DISTRIBUTION OF LARVAL AND JUVENILE *NOTOTHENIOPS LARSENI* AND *PLEURAGRAMMA ANTARCTICUM* OFF THE ANTARCTIC PENINSULA IN RELATION TO OCEANOGRAPHIC CONDITIONS

by

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ABSTRACT. - The vertical and spatial distribution of *Pleuragramma antarcticum* and *Nototheniops larseni* in the Bransfield Strait was studied during the BIOANTAR 93 cruise performed from RV "Hespérides" in Antarctic summer 1992/93. A multiple plankton net (Bioness) and a Bongo net were used to collect samples at 75 stations and one 24 h station. A number of depth layers (400-200, 200-150, 150-100, 50-20, 20-0 m) were sampled depending on the station. The water temperature and salinity profiles were analyzed to determine the association of species with water masses. Our data showed that the abundance of both *Pleuragramma antarcticum* and *Nototheniops larseni* is related to temperature. Abundance values exceeding 5 larvae/$10^3 m^3$ were seldom found when the temperature was less than 0°C. The relationship between larvae abundance and salinity seems to be inverse, although this result might be biased by the geographical distribution of stations and of sampled layers. In a 24 h station placed between Gerlache and Bransfield Strait, the most abundant fish larvae was *Pleuragramma antarcticum*, which were mainly found between 100-50 m and in warm waters (> 0°C). The daily migration of larvae in the vertical did not appear to be controlled by the oscillation of the pycnocline.

RÉSUMÉ. - Répartition des larves et des juvéniles de *Pleuragramma antarcticum* et de *Nototheniops larseni* au large de la Péninsule antarctique en fonction des conditions océanographiques.

La répartition verticale et horizontale de *Pleuragramma antarcticum* et de *Nototheniops larseni* dans le détroit de Bransfield a été étudiée pendant la mission BIOANTAR 93 sur le NO "Hespérides" pendant l'été austral 1992/93. Un filet à plancton multiple (Bioness) et un autre de type Bongo ont servi à échantillonner 76 stations dont une pendant un cycle de 24 h. Le nombre de profondeurs échantillonnées a été variable selon la station (400-200, 200-150, 150-100, 50-20, 20-0 m). Les profils de température et de salinité de la colonne d'eau ont été analysés pour déterminer les associations d'espèces avec les masses d'eau. Nos données ont montré que l'abondance de *Pleuragramma antarcticum* et de *Nototheniops larseni* est liée à la température. Des valeurs excédant 5 larves/$10^3 m^3$ ont rarement été observées quand la température était inférieure à 0°C. La corrélation entre les abondances larvaires et la salinité semble inverse, cependant ce résultat peut avoir été biaisé par la répartition géographique des stations et les couches d'eau échantillonnées. À la station échantillonnée pendant 24 h, située entre Gerlache et le détroit de Bransfield, les larves les plus abondantes étaient celles de *Pleuragramma antarcticum*. Elles ont été capturées entre 100 et 50 m à température supérieure à 0°C. La migration verticale nycthémérale n'est pas apparue liée à l'oscillation de la pycnocline.

Key-words. - Nototheniidae, *Nototheniops larseni*, *Pleuragramma antarcticum*, Antarctica, Bransfield Strait, Larvae, Vertical distribution.

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Most studies on the distribution of Antarctic fish larvae in the Antarctic Peninsula area have been conducted with grids of sampling stations at intervals bigger than 20 nautical miles, in an attempt to document larval fish distribution, abundance and assemblages (see Loeb *et al.*, 1993). Typically, these studies have used Bongo nets and other plankton gear and sampled obliquely, the resultant densities of larvae were generally quite low (Kellerman and Kock, 1988; Loeb, 1991; Morales-Nin *et al.*, 1995). The vertical distribution of Antarctic fish has not received a great deal of attention. Generally, studies have determined the abundance of larvae in two depth ranges 0-200 m and more than 200 m (Kellermann, 1986; Kellerman and Kock, 1988; Loeb, 1991; Morales-Nin *et al.*, 1995), although data on vertical distribution are more complete for the Weddell Sea (White and Piatkowski, 1993).

However, the temporal and spatial co-occurrence of larval stages of marine fishes depends on the time of hatching of the species and also on the location of the spawning grounds and subsequent dispersal by oceanic currents (Moser, 1981). But larval depth distribution and behavioural differences may also be involved (Loeb, 1991). Two of the main species in the Bransfield Strait during summer are *Nototheniops larseni* (Loenberg, 1905) and *Pleuragramma antarcticum* (Boulenger, 1902) (Kellermann and Kock, 1984; Kellermann, 1986; Slosarczyk, 1986; Morales-Nin *et al.*, 1995). We report here the vertical distribution of the larvae of these two species in the 1993 Antarctic summer as a continuation of the studies carried out previously (Morales-Nin *et al.*, 1995), in an attempt to provide some clues on larvae fish distribution patterns and their relationships with environmental variables.

MATERIAL AND METHODS

Larval fish were collected from 75 stations on Bransfield Strait and one nyctemeral station in the mouth of Gerlache Strait between January 19th and February 15th 1993 from the oceanographic vessel "B.I.O. Hespérides" (Fig. 1). The sampling gear was a multinet (Bioness) which consists of a rectangular 1 m^2 frame with seven 350 µm mesh nets. The Bioness system logged depth data, net water flow and net pitch at two seconds intervals. Standard procedure was to lower the net below the greatest sampling depth for the station, and to make an oblique ascending tow opening the nets in accordance with the desired depth ranges: 1000-400, 400-200, 200-150, 150-100, 100-50, 50-20, and 20-0 m. A Bongo net of 60 cm diameter and 350 µm mesh was used at shallow stations and down to 200 m depths when the multinet was not used; sampling depth was determined by length and angle of the towing wire. Towing speed was 2.5 knots with both nets. At the 24 h station twelve periods of the day at 2 h interval, and six depth strata (400-200, 200-150, 150-100, 100-50, 50-20, and 20-0 m) were sampled. Prior to the sampling operation, a vertical profile of temperature and salinity was obtained at each sampling station by means of either a Neil Brown MkIII CTD or an EGandG MkV probe.

Larval and juvenile fish were separated from the plankton samples immediately after each haul. Each larva was measured whilst fresh, and identified according to Efremenko (1983) and North and Kellermann (1990). Specimens were then immediately fixed in 4% formaldehyde-seawater solution, buffered at pH 8. Abundance estimates of larval fish were standardized to $10^3 m^3$ of seawater for each station and depth layer. The swept water volume for each net was determined from calibrated flowmeters (Pommeranz *et al.*, 1982). The Bioness swept volume calculations were adjusted for the effect of pitch on the net frontal area.

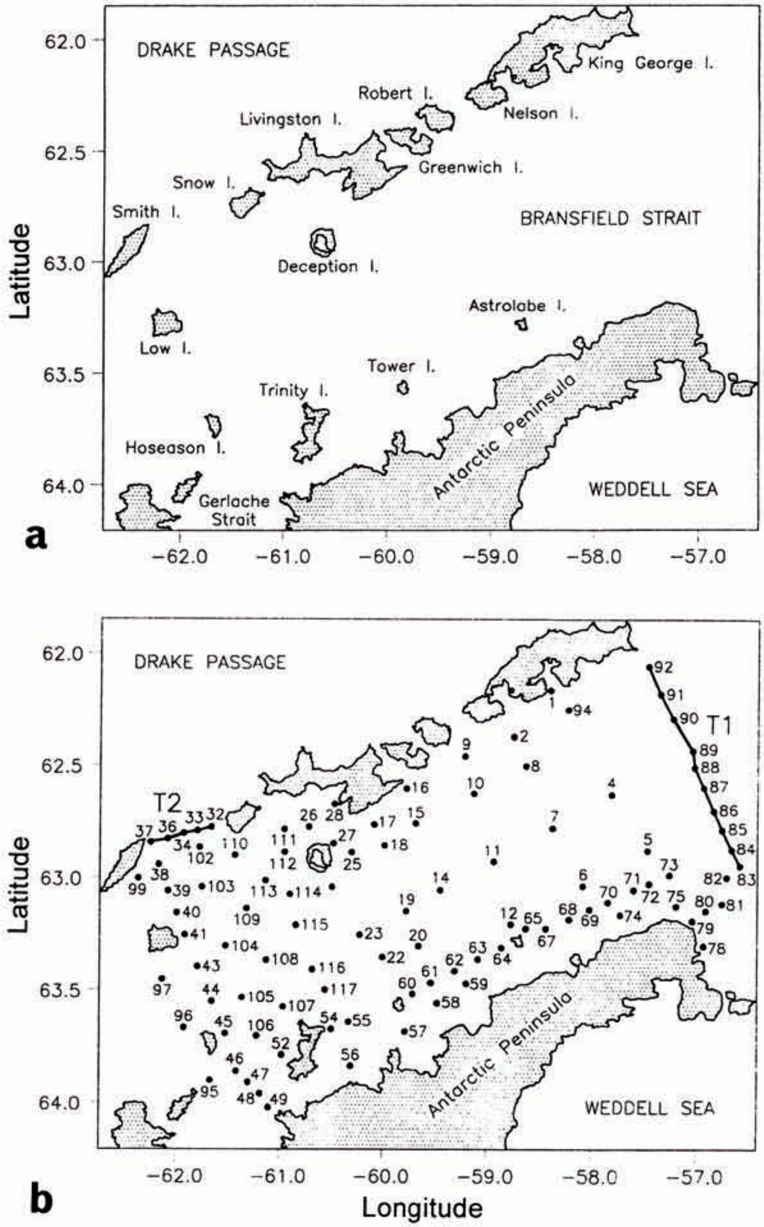


Fig. 1. - a: Location of Bransfield Strait. b: Sampling stations in BIOANTAR 93 cruise. T1, T2: see Figs 3, 4.

The vertical distribution of the fish larvae was determined on 14 transects (75 sampling stations and 99 CTD stations) running from the Antarctic Peninsula to the South Shetland Islands and west-east (Fig. 1) in order to determine their relationships with the shelves and the oceanographic conditions. Due to the low abundance of the lar-

vae, a separation of data by time of day was not attempted. Further information was provided by the 24 h station held on Gerlache Strait (Station 34).

The relationships between the larvae abundance, water temperature and water salinity were determined by simple linear regresion methods.

RESULTS

Local oceanographic conditions

The hydrographic structure of the Bransfield Strait is mainly controlled by the inflow of water mass from the adjacent Bellingshausen and Weddell seas. On the other hand, relatively warm, low salinity surface water from the Bellingshausen Sea enters into the Bransfield Strait, during the Austral summer, through the passages that exist between the westernmost South Shetland Islands and slope. Another stream of cooler water from the Bellingshausen Sea inflows through the Gerlache Strait and joins the previous jet. Also, cool and salty Weddell Sea water flows into the Bransfield Strait around Joinville Island and through the Antarctic Sound and circulate to the southwest along the western coast of the Antarctic Peninsula.

According to the results obtained by different authors during the Austral summer (see e.g., Sievers, 1982; Rojas, 1986; Niiler *et al.*, 1991; García *et al.*, 1994), the 1.0°C isotherm and 34.1 psu isohaline roughly define a surface frontal feature dividing what Tokarczyk (1987) names Transitional Zonal Water with Bellingshausen Sea influence (TBW) from the Transitional Zonal Water influenced by the Weddell Sea water inflow (TWW). This frontal feature can be easily identified in the surface temperature and salinity distributions obtained during the BIOANTAR 93 cruise (Fig. 2). The Weddell Sea water inflow conforming TWW entered into the Bransfield Strait as a weak southwestward flow along the Antarctic Peninsula continental shelf. At several sections accross the Antarctic Peninsula shelf, filaments of TWW detached from the stream towards southwest and flowed offshore (López *et al.*, 1994).

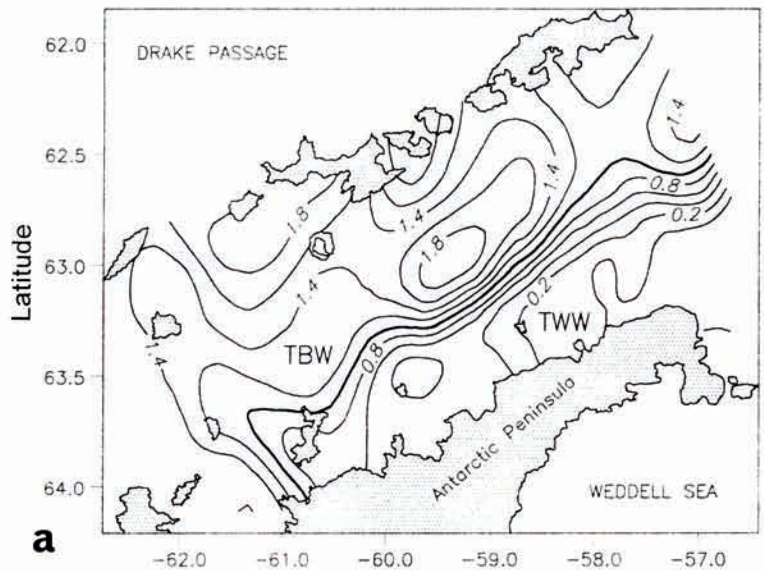
The vertical temperature and salinity distributions accross the Bransfield Strait shows that, whereas TBW is confined to the mixed layer, TWW extends as deep as 500 m (Fig. 3). Filaments of warm Circumpolar Deep Water (CDW, $T > 0°C$) intruded through the Boyd Strait and also between Smith and Low Islands at depths between 350 and 500 m and partially replaced TWW in the western basin of the Bransfield Strait (Fig. 4). The -1.0°C isotherm defines approximately the uppermost extend of the local Deep Bransfield Water, which is supposed to be formed locally by *in situ* convection of surface waters at the beginning of the winter season (Gordon and Nowlin, 1978).

Two sloping fronts can be distinguished at both sides of the Bransfield Strait in figure 3. The intense front on the South Shetlands side (right) is related to what has been termed the Bransfield Current (Niiler *et al.*, 1991). It was located some 50 km north from the surface frontal feature separating TBW from TWW.

Larval fish distribution

A total of 198 larvae and juvenile fish were caught in the cruise (Morales-Nin *et al.*, 1995). *Nototheniops larseni* and *Pleuragramma antarcticum* predominated both in number (42.4% and 31.3% of the larvae respectively) and in frequency of appearance.

The larvae and juveniles of *P. antarcticum* were found mainly near Low and Smith Islands and in the central-east area of the Bransfield Strait, while *N. larseni* was more



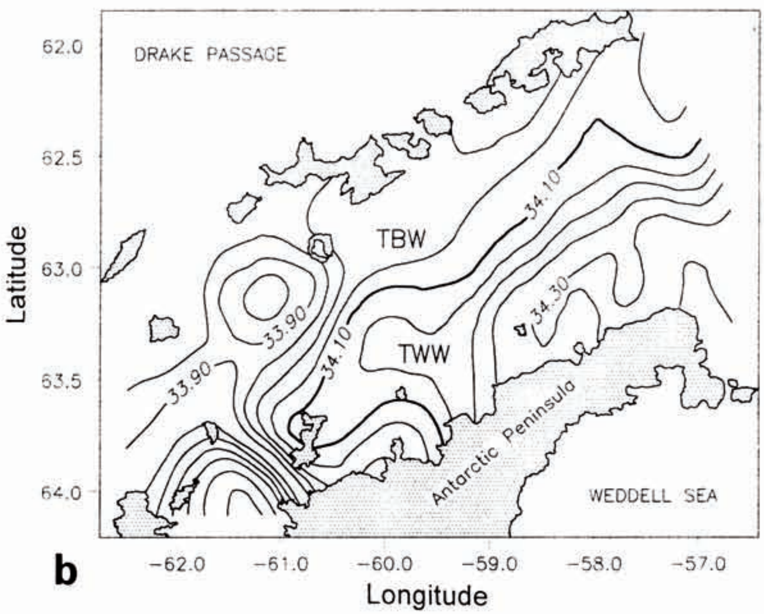


Fig. 2. - Distribution of **a**) temperature °C and **b**) salinity at depth of 10 m during the BIOANTAR 93 cruise. TBW: Transitional Zonal Water with Bellingshausen Sea influence; TWW: Transitional Zonal Water with Weddell Sea water inflow influence.

frequent near the South Shetlands and Low Islands (Fig. 5). Both species were found on the Antarctic Peninsula shelf and in the Antarctic Sound.

The larvae distribution showed the presence of larvae on the upper 200 m of the water column on stratified and relatively warm water ($T > 0°C$). The larvae were most

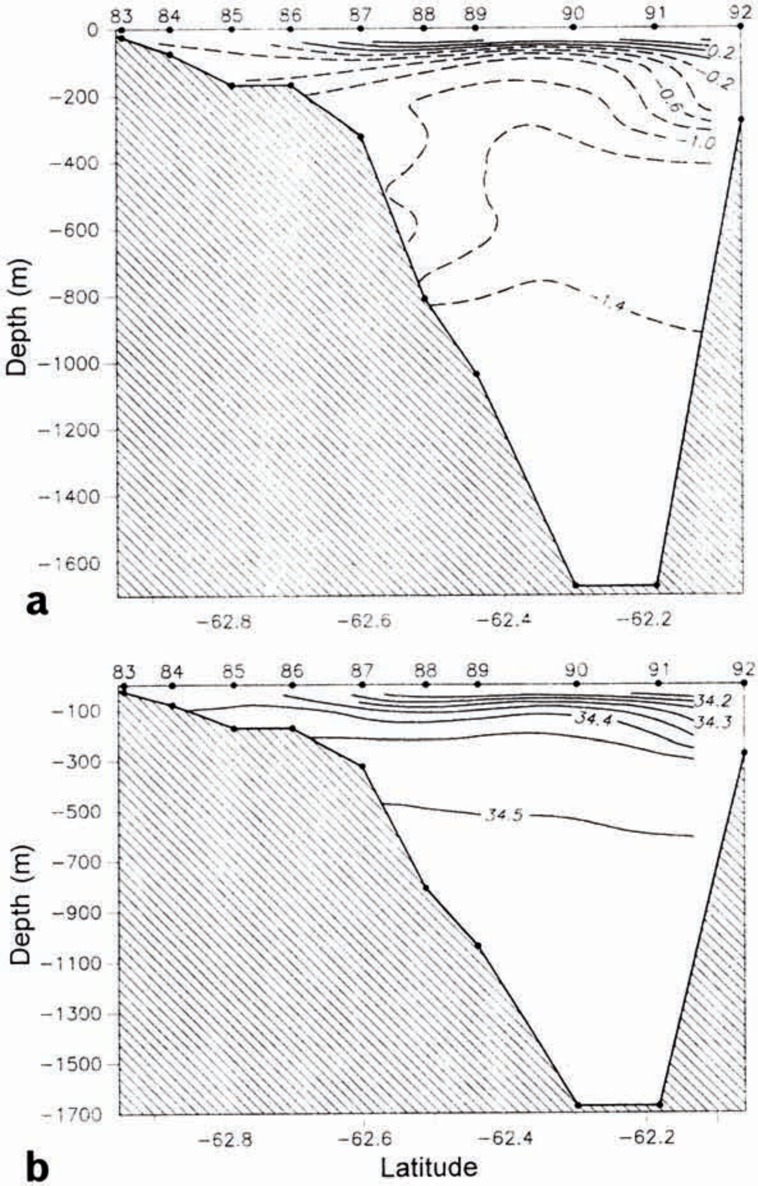


Fig. 3. - Vertical distribution of **a)** temperature °C and **b)** salinity at transect T0 (sampling stations 83-92; see Fig. 1b). The South Shetland Islands are on the right hand side.

abundant in shallow stations placed on the South Shetlands shelf, in which hydrography was mainly influenced by the flow of Bellingshausen Sea water into the Strait. *N. larseni* was found in only two stations deeper than 200 m (S60, S61), while *P. antarticum* was found only in 1 station deeper than 200 m (S3). In these stations the water temperature ranged from -0.8 to -1°C.

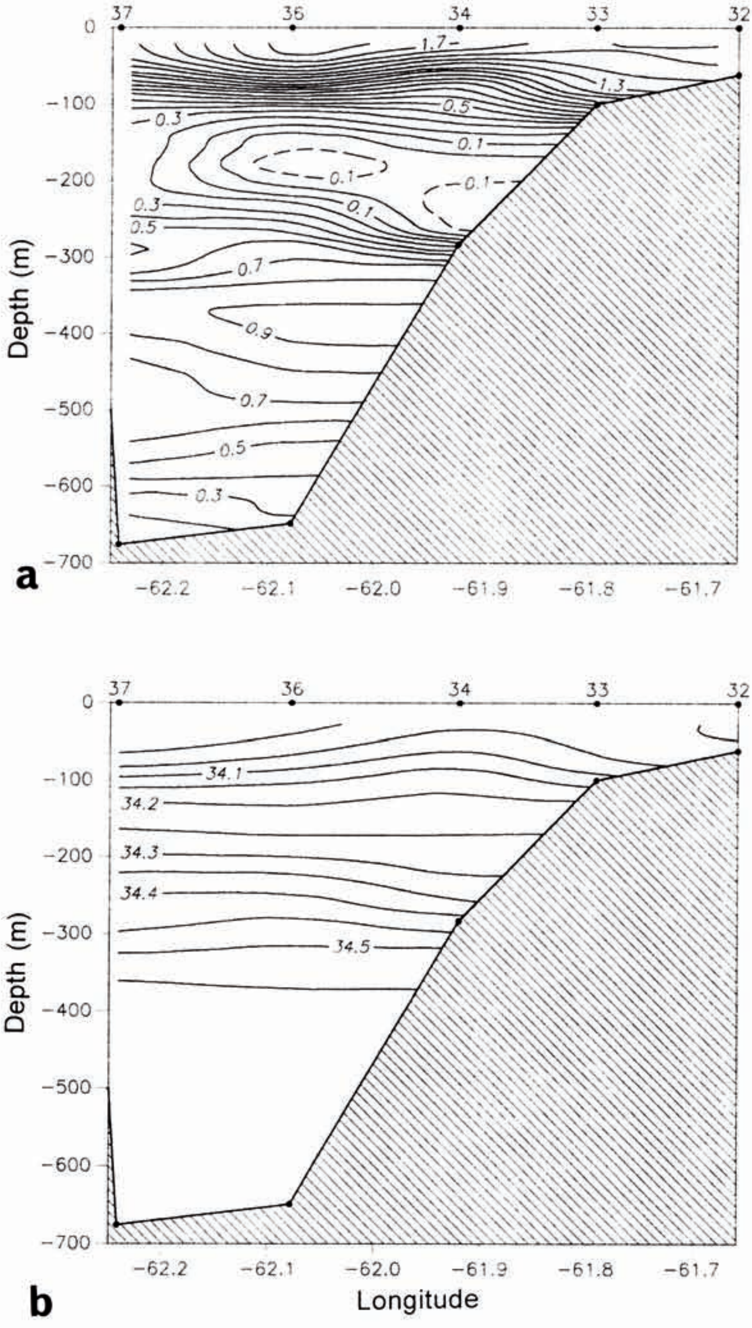


Fig. 4. - Vertical distribution of **a**) temperature °C and **b**) salinity at transect T11 (sampling stations 32,36-37; see Fig. 1b). The South Shetland Islands are on the right hand side. A warm filament of DDW (temperature up to 0.9°C) can be seen entering the Bransfield Strait between 350 and 500 m depth.

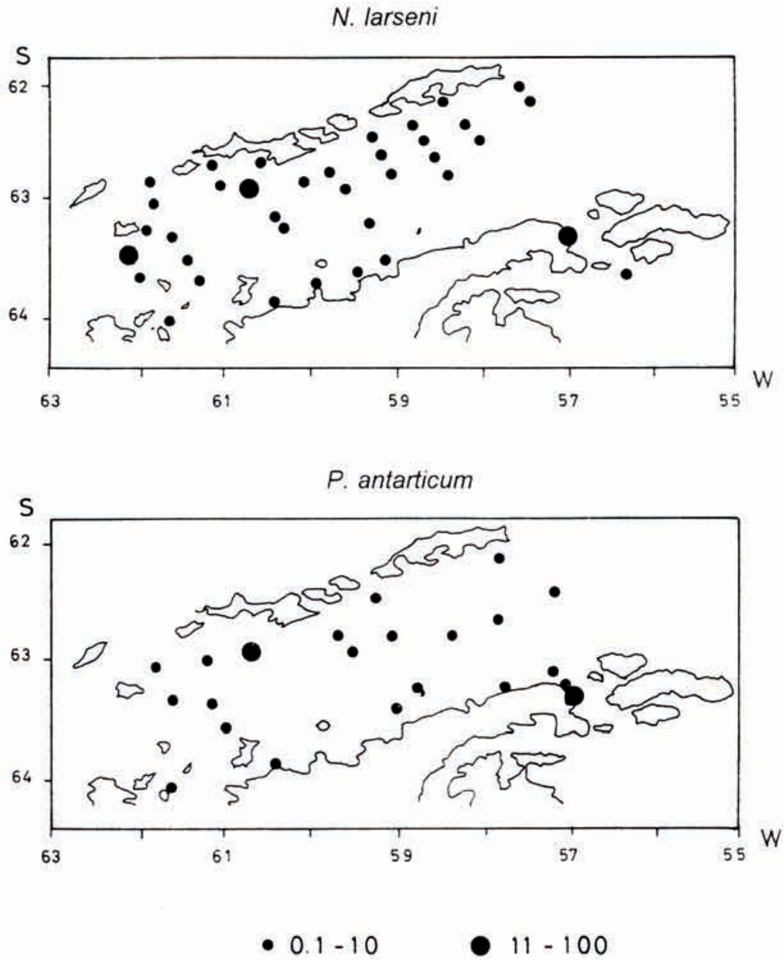


Fig. 5. - Occurrence and abundance of *Nototheniops larseni* and *Pleuragramma antarcticum* during the BIOANTAR 93 cruise (adapted from Morales-Nin *et al.*, 1995). Individuals/10^3m^3.

The relationship between water temperature, salinity and larval abundance was very low and not significant. Unlike this, the abundance of both *P. antarcticum* and *N. larseni* increases with temperature, although the dispersion of the values was high (Fig. 6).

In the nyctemeral station larvae were not present in two of the hauls and only 75 larvae were caught. The most abundant and frequent species was *P. antarcticum* with the 70.66% of the fish larvae caught and appearing in the 100% of the hauls were fish larvae were sampled, while only two *N. larseni* larvae were sampled. *P. antarcticum* was most abundant between 100-50 m in water above 0°C (mean abundance 10.95 larvae/10^3m^3), followed by the depth layer of 150-100 m (mean abundance 6.2 larvae/10^3m^3). Some fish were found in shallower waters, mainly between 50-20 m (2.84 larvae/10^3m^3), and were found only between 0-20 m at night. The change in the larvae distribution by depth

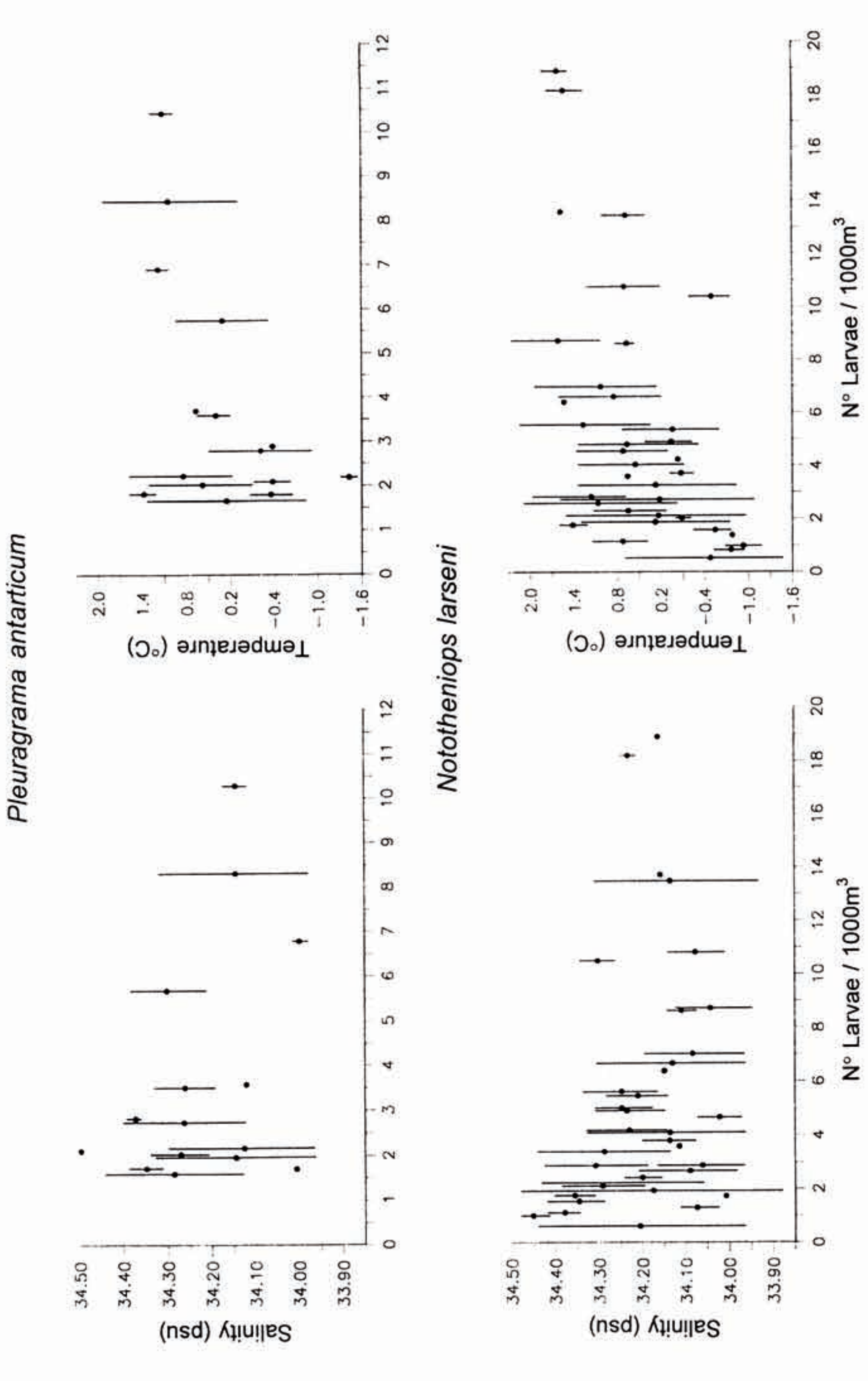


Fig. 6. - Relationships between temperature, salinity and abundance of *Pleuragramma antarcticum* and *Nototheniops larseni*.

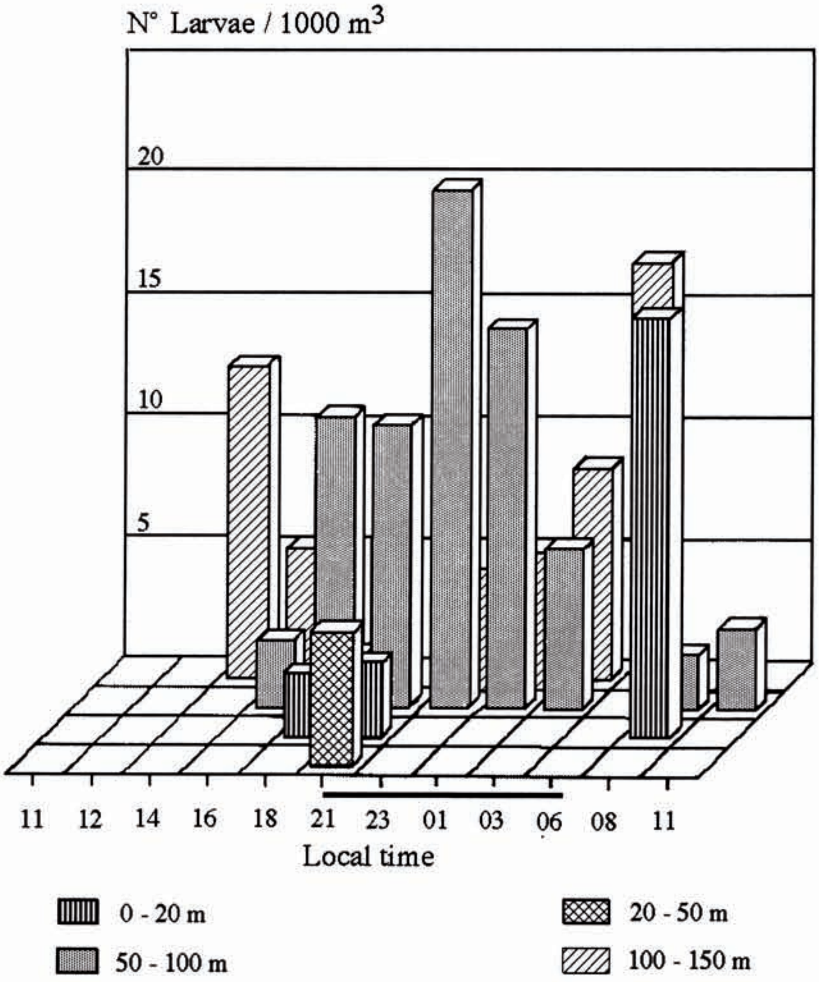


Fig. 7. - Vertical distribution of *Pleuragramma antarcticum* at the nyctemeral station (S34) at 2 h intervals along 24 h (local time).

along the 24 h study period showed clear variations (Fig. 7). The fish larvae were found in waters less than 50 m depth at dawn and sunrise. During the night they were concentrated betwen 50-100 m, and in deeper waters during the day. The abundance was related to depth (one-way ANOVA, $F = 2.701 > F_{05,18}$).

The water in the 0-100 m upper layer was warm (over 0°C) reaching around 1.5°C in the surface. Between 100-200 m the temperature was slightly superior to 0°C. The salinity was around 33.5 psu at the surface and increased to 34.5 psu at 400 m. The thermocline was about 45 m deep and showed a slight tendency to shallow at the end of the study period. The halocline and pycnocline were always below 50 m deep and oscillated in the vertical. Table I shows the estimated depth of the pycnocline as obtained

from the pressure averaged profiles recorded during the nyctemeral CTD vertical profile. The vertical excursion of the pycnocline seems to be not in phase with the local barotropic tide, which suggests that it might be associated with the internal wave dynamics. This hypothesis is consistent with the estimated amplitude of the halocline oscillation. Neither the temporal change of the physical structure of the water column matched with the observed variations in the vertical distribution of larvae. The maximum concentration of larval fishes at the 50-100 m layer was obtained when the halocline was deepest (about 90-95 m).

DISCUSSION

The spatial and seasonal distributions of larvae are initially established by spawning location and influenced by environmental conditions. The Bransfield Strait is a nursery area for larvae and early stages of fish derived from spawning stocks in the northwestern Weddell Sea and from the Bellingshausen Sea (Kellermann and Schadwinkel, 1991). The Strait is a 112 km-wide trough with a maximum depth of over 2,000 m, trending northeast to southwest for 460 km between the South Shetlands and the Antarctic Peninsula. Essentially, the Bransfield Strait waters are the product of the interaction between two different inflowing water masses from both the Bellingshausen and Weddell seas and of additional local influences (see e.g., Sievers, 1982; Heywood, 1985; García *et al.*, 1994). The complexity of the local hydrography, its seasonal variability and the presence of larvae derived from at least two different stocks (Kellermann and Schadwinkel, 1991) makes it difficult to clarify the trends and origin of the identified larvae.

Some authors have postulated the association of Antarctic fish larvae with the shelfs and shallow waters near the South Shetland Islands. This association seems evident

Table I. - Estimated depth of the pycnocline during the 24 h station (determined as maximum density difference in 5 m, from the pressure averaged CTD files).

Date	Local time	Estimated depth of the pycnocline (m)
4 February 1993	13:12	60-65
	15:12	65-70
	17:00	45-50
	19:00	55-60
	21:49	85-90
	23:09	90-95
5 February 1993	00:27	75-80
	01:30	75-80
	02:27	70-75
	03:34	85-90
	04:32	90-95
	05:34	85-90
	08:02	70-75
	19:25	70-75

when the horizontal distribution of the larvae is considered. However, when the vertical distribution of the larvae is considered, a relatively independence of the shelf or frontal structures is evident. The larvae appear to be associated to stable stratified water masses. Only in two occasions the larvae were found in relatively mixed waters. In all the other observations the larvae were found in warm stratified waters of Bellingshausen origin. This is in accordance with the reported preference of *P. antarcticum* larvae for the upper 50 m layer of statified Warm Summer Water (-0.5°C) on the Weddell Sea (Hubold, 1984). Although this species is dominant on the entire water column, it is more abundant in the upper 300 m, with most larvae on the 0-70 m layer except beyond the shelf-break front were most occurred at 70-200 m (White and Piatkowski, 1993).

The concentrations of larval fish in a determined water mass might be related to the time of egg dispersion and suitability for early larval survival. *P. antarcticum* appeared as large post-larvae suggesting that there was not hatching in the area. Probably the larvae proceeded of a spawning in the Bellingshausen Sea and have been passively transported by the water flow. However, the larvae behaviour in the nyctemeral station showed certain selection capability of the water flow by means of vertical migrations. *N. larseni* is common down to 400-500 m depth in the Bransfield Strait (Kellermann and Kock, 1988). This species was not found in Gerlache Strait during the same season (Morales-Nin *et al.*, 1995), suggesting a local origin.

However, the relative abundance of both species larvae on the Antarctic Sound might be due to a Weddell Sea origin in the east Bransfield Strait. *P. antarcticum* larvae are abundant over the shelf of the southern and eastern Weddell Sea (Hubold, 1984), with abundances 10 to 100 times superior to the values reported in this paper.

The low correlation of the larvae abundance to water temperature and salinity may be due to the optimal characteristics of the water mass were the larvae were found. Inside these range of conditions the larvae may be relatively independent of small variations of water parameters.

Larval and juvenile fish distributions in the Gerlache Strait appear to be the product of environmental influences on adult spawning, with some role by the behaviour in juvenile fish. Spawning by adults establishes the initial distribution of eggs and small larvae, but the local hydrographic conditions migh determine the dispersion of the larvae. Our results suggest a clear association of larvae to water masses but the larvae might somehow choose the water mass by means of vertical migration. The larvae were found mainly in the upper part of the water column in relatively warm stratified waters where their suvivorship should be optimal.

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